DESIGN OF A HIGH PERFORMANCE CONCURRENT SIMULATION SYSTEM

FINAL TECHNICAL REPORT

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13. ABSTRACT *(Maximum 200 words)*
We investigate methodologies and tools for the deployment of massively parallel simulation-oriented computations on a variety of hardware platforms, particularly heterogeneous networks of workstations. The underlying ideas are based in part on the prize-winning performance of the EcliPSe parallel simulation toolkit in the 1992 Gordon Bell Prize competition. The primary motivation is that the replication of computations involving statistical sampling be deployable through a transparent use of sequential codes. A major goal of this research is the design and experimental development of a high-performance simulation environment which enables large-scale computations in different problem domains. Besides execution performance, the research emphasizes low-effort and rapid simulator development, a feature invaluable in experimental research.

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Final Report (September 1, 1997)

In this project we focused on the design of a high performance concurrent simulation system. For this, we took an experimental software systems approach, based on our PVM/Conch experience, to study different aspects of support for high-performance distributed simulation on heterogeneous networks. We designed new algorithms and methods for deploying distributed simulations on heterogeneous processor clusters. We built a layered software prototypes, incorporating functionality for heterogeneous networked computing with threads and objects. We placed major emphasis on failure-resilient execution in one of these subsystems (i.e., EcliPSe).

Our research required us to delve into a number of related areas for which synthesis is not well understood, particularly with threads-oriented distributed computation. These areas include heterogeneous network computing, efficient networking (lightweight multicast protocols), distributed visualization, distributed naming and location, parallel stochastic and deterministic simulation, multithreaded operating systems, statistical computing and fault-tolerance.

Our research methodology and software enables users to create complex simulation models rapidly, because of the "process" orientation. Dynamic simulation units are viewed as processes – implemented as user-space threads, and static simulation units may be viewed as objects. Distributed simulations proceed both optimistically and adaptively. Our solution methodology is unique in two senses. First, there is virtually no commercial software available for (optimistic) distributed simulation. Second, our ParaSol system provides a simple API due to its process-orientation (i.e., its well-accepted that process-oriented models tend to be the easiest to design) that is supported by migratable threads. The thread migration support makes the system unique. To the best of our knowledge, this is the first known process-oriented parallel simulation tool.

We focused mainly on the ParaSol simulation object library for distributed simulation and implemented (a). the ParaSol kernel, based on an optimistic simulation protocol, and (b). a domain layer for manufacturing applications (queueing), which runs on top of the kernel. The kernel is C++ based, and is supported by our Ariadne portable threads library. We are currently investigating the layering of other application domains on top of the ParaSol kernel, potentially domains of interest to researchers at the ARL. Some projects under way include Professor Hisao Nakanishi's particle domain for polymer physics (Purdue), Dr. Danny Rintoul's materials science simulation domain (Princeton Univ. Material Science Lab.), Prof. Ferydoon Family's colloidal coagulation and stability models using the NVT method (Emory Univ.), and Professor Bruce Schmeiser's queueing domain for manufacturing systems (Purdue).

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Personnel

Scientific personnel supported include V. Rego, V. Sunderam, A. Krantz, K.-H. Chung, J. Sang, F. Knop, E. Mascarenhas, J.-C. Gomez.

Scientific Progress

This project has demonstrated several things: process-oriented parallel simulation is feasible, user-space protocols are very efficient, and a variety of services can be provided based on URLs. Our experimental research has brought significant gains in knowledge, particularly with respect to threads and thread migration, the use of threads in the design of kernels for optimistic simulators, experiences with the use of statistics-based protocol adaptation. Besides their use in protocols for simulation, we have found threads to be highly useful in the design of user level protocols in networks. Our experimental work on user level implementation of a variety of protocols is now continuing. We expect the communication protocols to be very useful in improving the performance of distributed applications.

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Awards/Honors

For each of the past several years, researchers on this project (students of Rego) have been given annual awards for the above work.

1. 1992: Rego and Sunderam are awarded the 1992 IEEE/Gordon Bell Prize for practical and large-scale parallel computing.
2. 1994: Janche Sang (Ph.D. Student) is awarded the 1994 Maurice Halstead Award in Software Engineering.
3. 1993: The first student from the group (with research fully supported by the Taiwan DoD during his stay at Purdue, and who graduated in 1993) was promoted to the rank of General in the Taiwanese Army.
4. 1995: Felipe Knop (Ph.D. Student) is awarded the 1995 Maurice Halstead Award in Software Engineering.
5. 1996: Edward Mascarenhas (Ph.D. Student) is awarded the 1996 Maurice Halstead Award in Software Engineering.
6. 1997: J.-C. Gomez (Ph.D. Student) is awarded the 1997 Maurice Halstead Award in Software Engineering.